Development of Semi-Spherical Screen VR System for Exploring Urban Environment

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Abstract

Semi-spherical screen VR system is introduced, which is under development as the main part of a distributed multi-user VR environment. With this system users can obtain more immersive stereo VR view than other conventional system. The implementation details are described, and the rendering method used in this system is discussed. In this method, whole view is rendered by dividing view volumes and processed by inverse distortion correction, which cancel image distortion caused by projection onto spherical screen.

Key words: Distortion corrected projection, multi-user VR, and Urban Environment.

1 Introduction

This paper introduces a semi-spherical screen VR system, which is under development as the main interactive tool of a distributed multi-user VR environment. The environment is targeted to support designers, who are unfamiliar with computer usage, to make construction plans of urban or big malls and, let the users view those designs and confirm their various performance. Urban environment has large amount of complexity, moreover it is difficult to reconstruct and so optimization of design is almost impossible. Considering buildings in malls, streets, and whole the city itself, there are the following difficulties:

- In the designing stage, there is no method to support the consistent mutual communication between city-design experts.

- It is difficult for the general public to understand the whole design. Only with usual computer displays, it is hard to make them consent. Immersive VR is a concrete candidate to solve these difficulties. However such large scaled data as the whole CAD-based design of city are too gigantic for present VR systems to play. Since the view angles of present H.M.D. type displays are not wide enough, people can't understand the sizes of structures in the city designs.

In order to solve these difficulties, the authors are developing new distributed multi-user VR system with immersive VR experience terminals. This system helps the communication between design experts, and also helps the general public to understand the design in an intuitive way. This paper describes the details of implementation of the immersive VR terminal, which utilizes a semi-spherical screen and enables users of the system to make more intuitive experience with city design data in VR or virtual city.

Hereafter, first other immersive VR systems are reviewed in section 2, next the present system implementation details are described in section 3, and the rendering method used in the present system is discussed in section 4.

2 Short Review on Other Immersive VR Displays

Before description of the semi-spherical screen VR system, a review of other display methods is made. As mentioned above, one popular method is using H.M.D. This method is superior on the point of interaction, however it has no advantage on usage of multi-user environment, and in the case of realizing wide view angle, H.M.D gets so heavy that natural experience is impossible. Other method is stereo-scopic big monitor or screen projection. This method can provide multi-user environment, but has shortage in the immersiveness because of picture edge effect. There is also a method to use larger screen projection. OMNIMAX is one example of this category, which projects pictures into an encircled screen surrounding the audience. This system is capable of multi-user environment; it is however rather large scale by itself, too expensive for the non-entertainment use. CAVE (1) is another and good candidate method; it has enough immersiveness and can provide multi-user environment. This system consists of 4 or 5 rear-projection screen, which are formed as a cube. This system, however, also has some difficulties on the projection around the corner or joint of two screens. It is possible to realize a continuous projection only for one user. Other users, who also view the picture in the same CAVE cube, only see discontinuous or edge-angled image. Semi-spherical screen projection VR, which is developed by the authors, provides multi-user environment such as in CAVE or in OMNIMAX. This system realizes a wide view-angle picture covers almost whole the users' sight. Although in this system the complete non-distorted image can be made only for one user, the other's vision is not so unnatural because there is no discontinuity in any place of generated picture.

3 Details of the Semi-Spherical Screen VR System

Details of the semi-spherical screen projection VR system are as follows:

This system consists of semi-spherical screen and six projectors, LCD shuttering stereo glasses, I.R. emitter, and of course, graphics computer. Figure 1, 4 and 5 show how the projectors and screen are placed, and Fig.2 and 3 are photograph of actual system. The size of screen is 6.8m in its diameter. Using six front projection type projectors, the system generates a picture as wide as 180-degree in horizontal direction, and 90-degree in vertical direction. As mentioned above, this angle is wide enough to cover user's sight. The graphics computer generates right-eye view pictures and left-eye ones reciprocally, using quad buffer. One picture is divided into six 640x480-size(up to 1024x768-size in near future) pictures for six projectors. For this purpose, the used graphics computer has 3-pipe dual-headed graphics devices. Combined picture from six projectors can have as high resolution as 1920x960 pixels. The screen material is soft type PVC. The semi-spherical form is actualized in the following way; construct a dome-like iron frame, cover it with the PVC screen material and vacuum the air from the inside of frame to make screen material attach to the spherical shaped frame. Needless to say, continuous evacuation is inevitable. The projectors selected in this system have the following features:

- Wide projection angle, 60-degree horizontally and 45 degree vertically, respectively.
- Acceptable high vertical refresh rate for better stereo scopic pictures.
- Focus on the curved screen.
- Blending mechanism is available. The boundary area between two projections may be brighter or darker than other areas. Blending mechanism can adjust such lines that offend eye (however this function has not yet been implemented; the lines are minimized by complicated manual adjustment).

4 The Rendering Method used int the present system

The most important issue on the system development is how to make a non-distorted image on the spherically curved screen.

Perspective view is a view from one point, usually means user's eye. According to the nature of

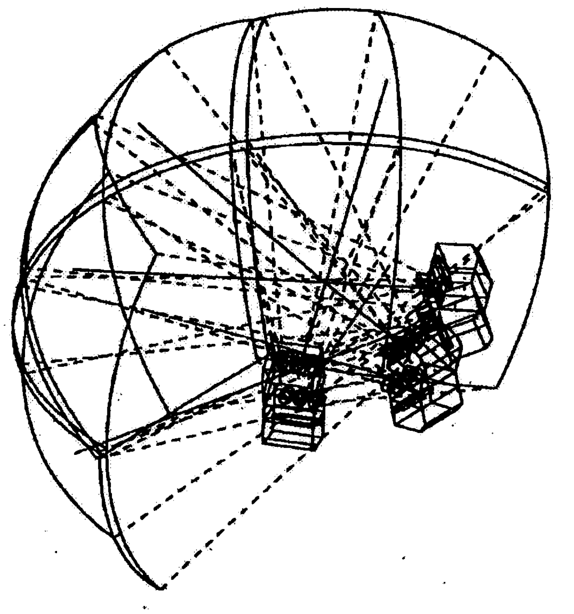

Figure 1: Configuration of projection system.

it, if a computer generated picture calculated with perspective projection is projected onto a sphere from an ideal point at center of sphere, and if the user sees the image from the same center of sphere, the image is completely correct one. Unfortunately, however, the computer generated image is rectangle, therefore the image as it is can not cover all the semi-sphere. And thinking real world projection systems, the following problems exist.

1. The real projector has a certain volume, so it can not be treated as a point.
2. Because of request for enough high resolution, a set of multiple projectors are used to make one image on the screen.

In other words, to make a such system actually, a well-arranged set of projectors is needed, and every one casts a restrictedly defined part of scene to its area decided by geometry. In this situation it is inevitable to perform a special image processing after generating usual VR rendering. This post-processing is so-called distortion correction, and it can be considered as some kind of texture mapping process. This process is described as follows:(See Fig.7, 8 also.)

Suppose a certain rectangle $\mathcal{R}$ that is part of an image output by one graphics pipe and fed into one projector. Note the total image generated by one conventional rendering process is rectangle area. Once a rectangle image is projected onto a spherical screen, a distorted shape $\mathcal{S}$ appears at a certain area of screen. The contents must be contained in the distorted image are calculated from the usual perspective viewing algorithm. When the viewpoint position is given, because, naturally, the geometry of spherical screen is given, the part of the view volume $\mathcal{V}$ is decided. It is a distorted rectangle $\mathcal{A}$ on the final viewport outputted from usual rendering process. Therefore the whole rendering procedure is as follows:

1. Rectangle area $\mathcal{T}$ that contains the distorted projected image $\mathcal{A}$ area is defined,
2. draw a image for that rectangle $\mathcal{T}$ area using usual perspective projection method,
3. extract the distorted rectangle area $\mathcal{A}$ and distort it to the final rectangle $\mathcal{R}$ which will be output from computer.

The last stage of this procedure can be considered as a texture mapping which uses the just rendered

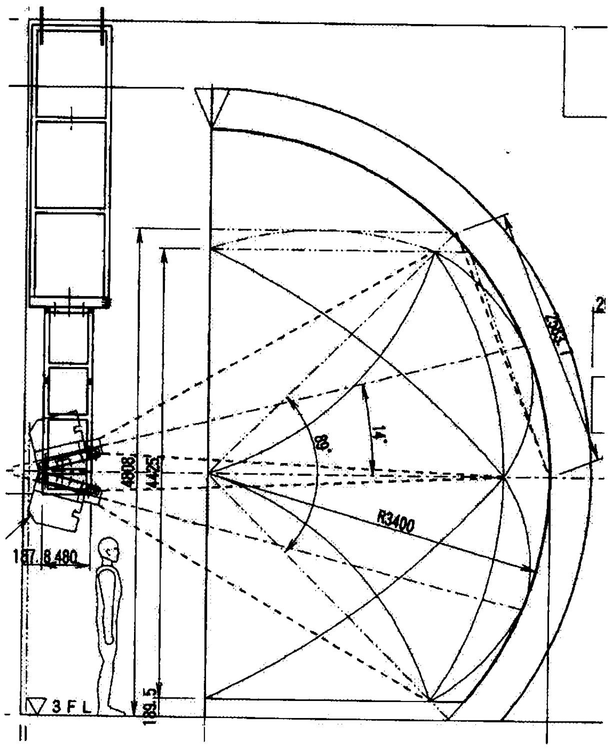

Figure 4: Plan view of system.

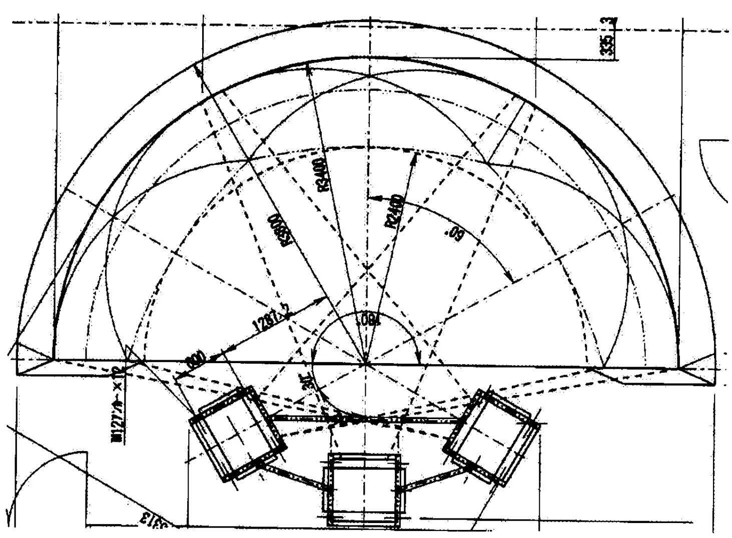

Figure 5: Elevation view of system.

image as a texture data. Therefore on some platform , hardware assist can be used. Infinite Reality Graphics from SGI, which used in our system, has such hardware assist feature named distortion correction function.

Total process is described as follows:

$$D \cdot D^{-1}[V \cdot N \cdot P \cdot M]\vec{x},$$

where $\vec{x}$ is a set of coordinate of a point and V is viewport conversion matrix, N is normalization, P is projection matrix, M is model view matrix, D distortion matrix by real projection, and D^{-1} is a inverse distortion matrix discussed here. However, because the physical projection correction is made to the projector itself, and usually this is ad hoc working, D is not generally defined and this leads the D^{-1} is not defined generally, only given by the measurement of real D. The number of division of whole view can be from two to infinity. Note this number is independent from number of projectors used in the system.

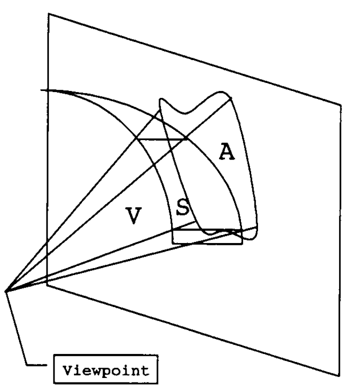

Figure 6: Illustration of view geometry for stripe of screen.

If the number is only one in horizontally 180-degree view system, the view volume must contain whole 180-degree view, however this is impossible from nature of perspective projection. If the horizontal viewangle is little less than 180-degree, the method itself is valid and can be used, however the whole image must be rendered at first becomes gigantic or the center part becomes too small from resolution consideration. If the number is large, each part distortion is enough small, however the division results need of many rendering processes, can cause inferior performance.

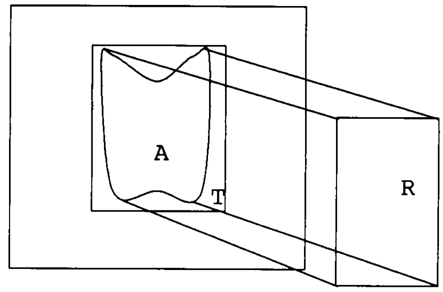

Figure 7: Inverse distortion mapping.

At present implementation, the number is identical to the number of projectors, so each graphs pipe draws its part and distorts the image from the geometry and make final output image.

5 Stereo Viewing

In order to make a stereo view, the present system needs simply to set 2 view positions for right and left eye view respectively and draw two images and show them through LCD shutter glasses. However to speak strictly, only one person's right eye and left eye positions are realized. In other words, if there are some other users, they can not get correct stereo view. Moreover, to make a correct stereo image, continuous measurement of user's eye position and movement of the viewpoints to the valid positions at each frame are needed.

With dividing view volume method described in the previous section, different right-left eye position pairs can be used. If right and left eye position are located on the plane which is paralleled with far clip plane of each view volume, users are able to get stereo view at the direction. So this method may be thought realize omni-direction stereo vision. However the stereo images located side by side with such method are not continuous with each other, strictly.

Experiments to draw image for only one users eye position are performed, and they show that the result images are enough natural in all directions. Of course those images are not perfectly correct for other users, but practically the method can be used.

6 Discussions

The present system has insufficient frame rate. The optimal number of divided view volume is still open. Though the number of projectors is used in the present system, increasing the number may make more frame rate, because there is possibility that the distortion without correction can be negligible when using small view volume. Moreover, it can be possible to make use of parallel processing when dividing view volume.

7 Concluding Remarks

A semi-spherical screen VR system is developed. Users can obtain stereo VR image surrounding themselves. The system is more immersive than other system. The dividing view volume rendering method used in the system is described. Because the present system has not enough frame rate, the further improvement for rendering parameters is needed. In our research project, data optimization and smart management of level of detail are also studied. Next, the all components are planed to merge into one system.

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References

1 C. Cruz-Neira, et al.: Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE, Computer Graphics (Proc. ACM SIGGAPH '93), pp.135-142, (1993).